9P-12-6

Surface Morphology Changes of CVD-Graphene/Cu(103) Induced by Post-Annealing Processes

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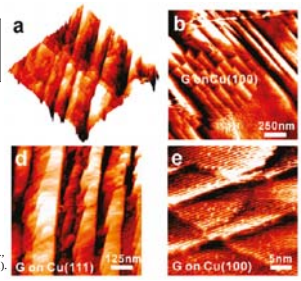
Innovative R&D by NTT

Motivation and aim

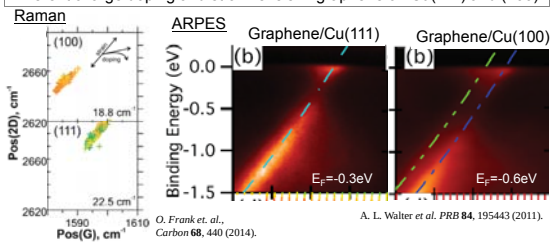
- Chemical vapor deposition (CVD) of graphene over Cu surface is promising for uniform, large-scale growth.
- Cu's crystal orientations affect surface morphologies, charge doping, and mechanical strain in graphene.

Surface morphology variations of graphene grown on polycrystalline Cu



Y. Zhang *et. al.*, *ACS Nano* 5, 4014, (2011).

Different charge doping and strain levels in graphene on Cu(111) and (100)



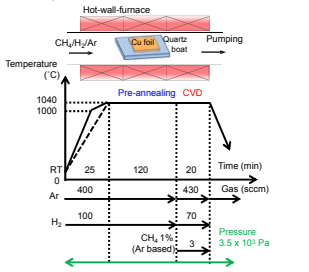
O. Frank et. al., Carbon **68**, 440 (2014).

A. L. Walter *et al. PRB* **84**, 195443 (2011).

We investigated surface morphologies and post-annealing effects of CVD graphene grown on Cu(103).

Experiments

1.Graphene CVD *Cu foils: Alfa Aesar (99.8%)



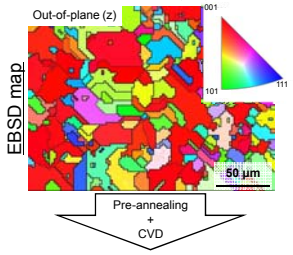
2. Post-annealing

Pressure: 7.5 x 10^{-7}~8.5 x 10^{-9} Pa
Temperature: 200 - 700˚C / 100˚C steps
Time: 10 min

Results and discussion

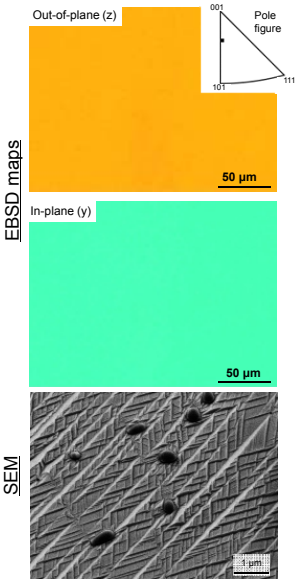
Crystal orientation of Cu

Non-annealed: polycrystalline

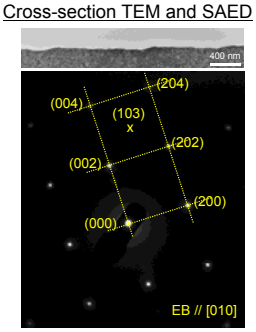


Pre-annealing + CVD

As-grown sample: Cu(103)

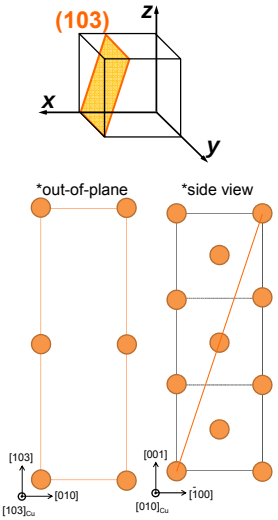


Cross-section TEM and SAED

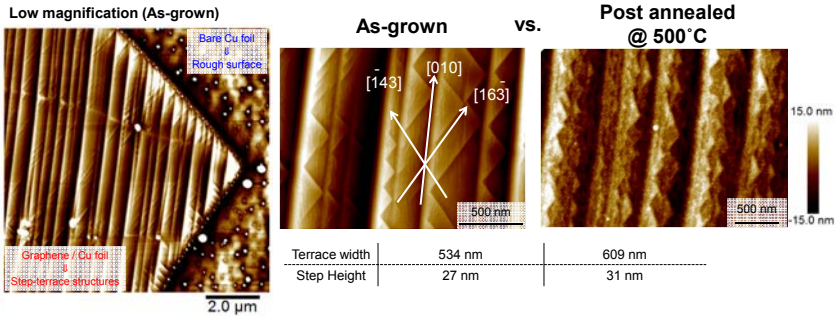


- ✓ Pre-annealing process provided single crystalline Cu(103) grain.
- ✓ The Cu(103) covered by single-layer graphene showed unique surface morphologies with (100) facets.

FCC unit cell and atomic arrangement of Cu(103)

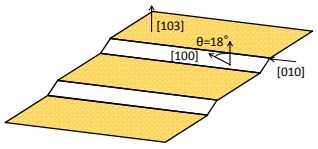


Step-terrace and facet structures on Cu(103) by AFM



	As-grown	Post annealed @ 500˚C
Terrace width	534 nm	609 nm
Step Height	27 nm	31 nm

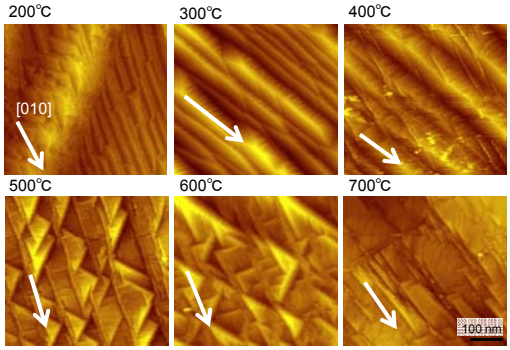
Schematic model of unchanged step-terrace structures



As-grown samples
- ✓ There are step-terrace structures bunching parallel to Cu [010] direction with 500- to 600-nm wide terraces in the Cu(103) covered by the graphene.
- ✓ Triangular facet patterns in the Cu[1̄43] and [163̄] directions appear.

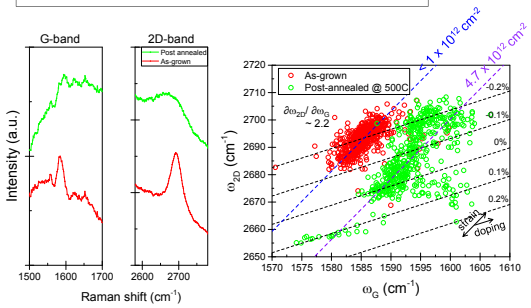
Post-annealed samples at 500˚C
- ✓ The step-terrace structures remained unchanged.
- ✓ The triangular facets on the terrace area became smaller.

Surface morphology changes on the terraces by STM



- ✓ Facet patterns on the terraces were changed by post-annealing at each temperature.

Frequency shift in Raman spectroscopy: G-band and 2D-band



- ✓ As-grown graphene showed lower doping level than1 x 10^{12} cm^{-2}.
- ✓ Post annealing induced 4.7 x 10^{12} cm^{-2} hole doping in the graphene. Furthermore, we observed partially released mechanical strain.

Summary

- Cu (103) covered by graphene had step-terrace structures with triangular facets on the terrace. The step-terrace structures were preserved during the post-annealing, while the facets patterns were changed.
- Results of Raman spectroscopy indicated that graphene on Cu(103) had 1 x 10^{12} cm^{-2} doping level and that the hole doping was increased by the post-annealing.

Acknowledgments: JSPS-CNR Bilateral Researcher Exchange Program (Joint Research Projects)

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